(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
25 April 2002 (25.04.2002)

PCT

(10) International Publication Number
WO 02/33441 A1

(51) International Patent Classification⁷: G01T 1/178

(21) International Application Number: PCT/GB01/04266

(22) International Filing Date: 26 September 2001 (26.09.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0025617.2 19 October 2000 (19.10.2000) GB

(71) Applicant and
(72) Inventor: SMITH, Arthur, Ernest [GB/GB]; 24 Mayfield Road, Farmoor, Oxford OX2 9NR (GB).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

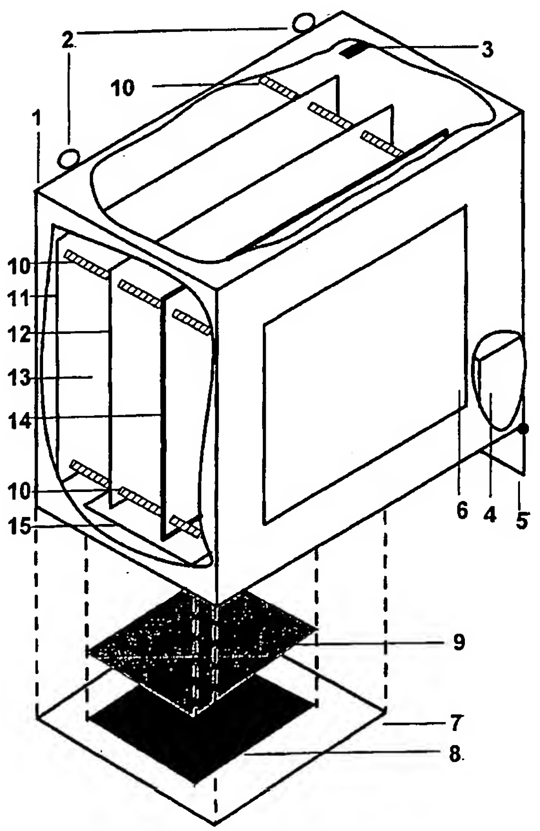
(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declaration under Rule 4.17:
— *of inventorship (Rule 4.17(iv)) for US only*

Published:
— *with international search report*

[Continued on next page]

(54) Title: DETECTOR FOR AIRBORNE ALPHA PARTICLE RADIATION



(57) Abstract: In the field of protection from ionising alpha particle radiation there is a need for a low cost, reliable, maintenance free, and self contained detector that con monitor continuously over a plurality of time periods the levels of airborne alpha particle radiation. The detector operates by measuring the charge created by alpha particle decay between electrodes in an enclosure. Detectors may be linked together to monitor several parts of a building or a large area of applications such as civil emergencies and earthquake warning.

WO 02/33441 A1

DETECTOR FOR AIRBORNE ALPHA PARTICLE RADIATION

This invention relates to the field of detectors for ionising alpha particle radiation from airborne radioactive nuclei that use ambient air as the detection medium.

The US National Academy of Sciences report BEIR VI (released 19th Feb. 1998) indicates that the pollution of buildings by radon (a naturally occurring radioactive noble gas) causes about 15,000 lung cancer deaths per annum in America and corresponding mortality elsewhere. Radon levels are not predictable: adjacent buildings of similar construction often have very different interior levels of radon and high levels of radon are found over various bed-rocks. The American Environment Protection Agency (EPA) recommend that every dwelling be checked for radon. Fortunately if radon pollution is detected it can be reduced by simple and inexpensive techniques. Continuous measurement of radon is desirable because levels change due to tectonic plate movement, seasonal heating and ventilation changes and building modifications, and to validate protection methods. Additionally radon levels often change before earthquakes (see e.g. Science Volume 269, 1995 p60.) Monitoring radon levels in real time across a large area, for example around known fault lines, and communicating these observations over a network to responsible persons may be used to warn of an imminent earthquake. Because the radiation exposure may vary with time so that e.g. the total exposure over say 24 hours may consist of several hours of high levels of airborne alpha particle radiation with lower levels for the other hours, it is desirable to sample the level of radiation over a plurality of time periods. Other potential sources of airborne alpha particle radiation include plutonium and uranium. Such elements may be put into the atmosphere by mining, accidents at a nuclear reactor or nuclear fuel or weapons processing facility or with a nuclear weapon or weapons, or military conflict with nuclear weapons and or depleted uranium munitions, or military conflict or terrorist action in which sites containing radioactive material are attacked, or by natural disasters such as earthquakes or volcanoes. Following such releases alpha particle radioactive material may remain in the air for considerable periods, or be deposited on the ground and then returned to the atmosphere by winds, agricultural activity, vehicle

movement and such. It is desirable to have detectors that provide real time warning of airborne alpha particle radiation. If such airborne radiation is detected, simple actions such as changing building ventilation and/or using simple filters, such as handkerchiefs, over the mouth can reduce exposure and risk of illness. Such detectors may also be networked together to provide an overall picture of the levels of airborne alpha particle radiation.

Two classes of practical alpha particle detectors exist. (1) Low cost devices with no real time monitoring, that are deployed for extended periods. Usually only the integrated radon exposure is determined, often after laboratory processing. (2) Sophisticated and expensive detectors that require skilled operators and which provide real time data. Devices based around ambient air ion counters exist in both classes. Low cost ion counters detect the rate of decay of a charged electrode, such as an electret, caused by ionising radiation. Sophisticated ion counters may detect an integrated direct current caused by atmospheric ionising radiation, or count individual alpha particle decays either with sophisticated low-current measuring apparatus such as Keithley (of Ohio, USA) electrometers or with sophisticated digital signal processing (DSP) techniques. Because of the inherent slow charge collection of atmospheric ion counters conventional fast signal shaping can not be used and such detectors are often troubled by microphonics necessitating careful disturbance free siting and/or sophisticated DSP techniques to prevent erroneous measurement. Such requirements are incompatible with the robustness, maintenance free operation and low cost essential for a mass-market detector. All of the prior art has disadvantageous features including expense and sophistication necessitating skilled operation, the long time delay between measurement and results, the absence of long term real-time measurement, the size and bulk of the detectors, and the sensitivity to microphonics. Such disadvantages have prevented the large-scale use of continuous readout radon detectors. There has not previously been a proposal for a truly practical detector for airborne alpha particle radiation that can be sized suitably for domestic applications and which provides continuous measurement over a plurality of time periods, requires minimum

maintenance and is easily manufactured from commonly available components, and which does not require a specially trained person to operate.

There are three key features of this invention that differ from the prior art. The first is that passive and common feedback components are used with common integrated circuit amplifiers to provide large electronic gain only for the characteristic signals from radioactive decay and low gain for other signals. This excludes the detection of air ions (atoms and molecules of the air that have lost or gained electrons so that they are charged) created by other sources such as electrical storms etc. The use of simple passive feedback components leads to simple manufacturing and reliability. The second is that a vibration sensor or a plurality of such sensors is used to detect disturbances that may otherwise produce erroneous measurements due to microphonics. While such disturbances remain data acquisition is stopped and the time of stoppage (dead time) noted to facilitate an accurate measurement of the rate of radioactive decay. The third is that the sensitive region of the counter is chosen so that a fraction of the radioactive decays occurring within this region will have short tracks striking the insensitive boundaries before producing sufficient numbers of ions to be detected. The detection efficiency may be substantially less than 100%. By so restricting the dimensions a counter sized convenient for domestic use is possible. Additionally because the first daughter (218 polonium) of 222 radon (the most common pollutant) is formed as a positive ion there is a probability it will become attached to the negatively charged electrode. 218 polonium and another daughter (214 polonium) also emit alpha particles, so that after a radon 222 nucleus decays, their will, within a few hours, be two subsequent alpha particles. Additionally 210 polonium that is formed via 210 lead (half life 22 years) also emits an alpha particle. Detectors operated in high levels of 222 radon may, after several years, become contaminated with 210 lead and will need cleaning or replacing or the contamination may be modelled and a correction factor based on exposure calculated. The absolute detection efficiency of any given electrode configuration can be determined by placing the detector in an environment of known radioactivity and/or by numerical modelling and comparing the measured or calculated detection rate to the known source, or numerically simulated, strength. The correction factor determined is used to convert measured rates to true levels. It is important to note

that only one such measurement or computation is needed for any particular electrode geometry that may be produced. Once a correction factor has been determined for a particular electrode configuration the production of detectors with this electrode arrangement does not require additional correction factors to be determined.

According to the present invention there is provided a detector for airborne alpha particle emitting nuclei comprising an electrically screened container with an aperture covered by an electrically screened filter through which radon or other airborne alpha particle radioactive elements can ingress by diffusion into said container and/or with an aperture that may be closed off through which radioactive material such as dust may enter the container through an appropriately sized electrically screened filter, a plurality of electrodes mounted inside and electrically isolated from said container, adjacent electrodes being so separated that a fraction of the radioactive decays occurring within the space between adjacent electrodes may have short tracks striking the insensitive boundaries before producing sufficient numbers of ions to be detected so that the detection efficiency may be substantially less than 100%, a means for providing a substantially smooth high voltage so that an electric field of strength needed to collect air ions produced by alpha particle radioactive decay exists between adjacent electrodes, a means to provide electrical power to an electronic circuit board containing an electronic charge sensitive pre-amplifier and an amplifier with passive feedback components that provides large electronic gain only for the characteristic signals from radioactive decay and low gain for other signals, and an electronic amplifier to amplify signals from a vibration sensor or sensors mounted inside said container, and electronic digital logic circuits, said circuits being so arranged to convert analogue signals from the amplifiers to digital signals, to count the number of ion signals and record the live time when there is no vibration signal or signals and to convert measured decay rates into true decay rates, over a plurality of time periods, a display unit, optical or audio or both, to indicate measured airborne alpha particle rates, and alarms (optical, audio or both) for rates exceeding official safe levels and for dead time.

Specific embodiments will now be described by way of example only and in no way restrictive of the scope of invention with reference to the accompanying drawings in which:

Figure 1 is a schematic drawing of an embodiment of the invention where the electrodes are two parallel plates.

Figure 2 is a schematic drawing of the electrical connections in one embodiment of the invention where the electrodes are two parallel plates.

Figure 3 is a schematic drawing of the electronic amplifiers in one embodiment of the invention.

Figure 4 is a schematic drawing of the electronic amplifier for a vibration sensor in one embodiment of the invention.

Figure 5 is a schematic diagram of an amplified waveform of the air ion signal produced by a 5.5 MeV alpha particle in an embodiment of the invention.

Figure 6 is a schematic drawing of an electronic digital circuit that may be used to reject counts that are associated with a simultaneous, or shortly thereafter, signal from the vibration sensor in an embodiment of the invention.

Figure 7 is an embodiment of the invention where the electrodes are two concentric cylinders.

Figure 8 is an embodiment of the invention where the electrodes are four parallel plates.

Figure 9 is a schematic diagram of the electrodes in one embodiment of the invention where the electrodes consist of three parallel plates.

Figure 10 is an embodiment of the invention where there is provided a moveable cover over an aperture that contains an electrically conducting grid of sufficient size to permit the ingress of radioactive dust between the electrodes inside the electrically screened container.

Figure 11 is a schematic diagram of a deployment of an embodiment of the invention providing whole building monitoring.

Figure 12 is a schematic diagram of a deployment of an embodiment of the invention providing monitoring over a large geographical area.

As shown in Fig 1 an embodiment of the invention comprises 1 an electrically screened container that shields the inside against external electrical interference. It may be secured to a vertical surface such as a dwelling wall using support 2, or it could be secured to a horizontal surface using other (not shown) support and fixing points. Anti-vibration material (not shown) may be used to reduce the intensity of vibration that may be transmitted to the invention. Inside the container there is provided a vibration sensor 3. A battery or batteries 4 are provided inside the container. These can be inserted by opening electrically conducting flap 5 and then after the batteries are inserted, closing it so as to provide electrical screening. A display and alarm unit 6 is placed on the front of 1. A plate 7 containing a fine metallic grid 8 is attached, so as to support filter 9, to container 1 in such a manner that the filter 9 and grid 8 cover an aperture 15 in 1 so that radon or other radioactive alpha particle emitting gases may diffuse through filter 9 into container 1 and so as to maintain electrical screening. The filter is also sized to forbid the entry of dust or similarly sized atmospheric pollutants and insects. Four good electrically insulating materials 10, such as Teflon (RTM), that contains an appropriately strong centre member, provide support and uniformly space apart and electrically insulate from each other electrically conducting plates 11 and 12. A plurality of additional supports (not shown), that provide good electrical insulation and that may also reduce transmitted vibration to plates 11 and 12 and that may also ensure

uniform spacing between the plates may be attached to the inner surface of 1. An electronic circuit board 14 is provided within enclosure 1, which may be electrically screened from the plates. One of the plates is connected to a high voltage so that an electrical field (10 to 20 volts/millimetre or larger) of sufficient strength to collect air ions is provided in the space 13 between the plates. The high voltage may be continuously applied from a high voltage battery or a plurality of such batteries, or be applied continuously by an electronic circuit, or the voltage on the plate may be sensed and re-applied when it has fallen, or the voltage may be re-applied at periods sufficiently close together so that a sufficient electrical field to collect ions is maintained between the electrodes. The current consumption of the charged electrode is very low so that a small amount of power is consumed in maintaining the electric field. Power for the electronic circuits may come from a battery or a plurality of batteries, from the mains electrical supply (not shown) or from solar panels (not shown) with backup for hours of darkness (not shown). The high voltage may be derived from a Dry Pile (not shown) sometimes called a Dulac or Zamboni Pile. Such a Pile may be useful for long duration deployment in subterranean sites where long life is needed; Piles have operated continuous for over 160 years. In the case of battery operation when the batteries need replacing, or if they are rechargeable when they need recharging, some method of alerting the user, such as an audio, optical or combination indicator, is provided. The electrical connections to the electrically conducting plates and to the electronic circuit board are shown schematically in Fig 2. Plate 12 is electrically connected to a source of high voltage and electrically insulated from 1. The air ion signal (not shown) is taken from plate 11, which is electrically insulated from 1, along conductor 16 to the electronic circuit board 14. The vibration sensor 3 is also connected to the electronic circuit board by conductor 17. Electrical connection 16 is connected (Fig 3) to a charge sensitive amplifier build around IC1 which may be a low cost and low power FET input operational amplifier (such as a TL061 or similar) as shown schematically. The feedback resistor R1 maybe 100 Mega-ohm. It may be coated to minimise charge leakage. The feedback capacitor C1 maybe 1.8 pF. Other values may be used. Connections to the circuit board may be made on to good quality electrical insulators such as Teflon (RTM) to minimise charge leakage. The output of this

amplifier is connected to a second amplifier build around IC2 (which again may be a TL061 or similar) as shown schematically in Fig 3. The feedback components around IC2 are chosen to give very high gain for the characteristics of the signals produced by air ions (not shown) created by airborne alpha particle radioactivity, and low gain for signals that have different characteristics resulting in minimal sensitivity to air ions not created by ionising alpha particle decay in region 13. The number of air ions that can be created by terrestrial gamma and beta radiation along with secondary radiation from primary cosmic rays in region 13 are too few to be detected. Typical values maybe: R5 is 47 k-ohm, C2 is 0.6 micro-farads, R2 is 500 ohm, R4 is 500 k-ohm, C3 is 640 pF, R3 is 12 k-ohm. Some variations may be made in the magnitude of these components. Other electronic circuits can be used to achieve the required performance. The electrical connection from the vibration sensor is fed to the amplifier built around IC3 (which may be a TL061 or similar) as shown schematically in Fig 4. R8 may be chosen to match the impedance of the vibration sensor, which for some, such as bi-morph sensors, is typically 1 M-ohm, R6 maybe 1 k-ohm, R7 maybe 1 M-ohm. Some variations in these components may be made. Other electronic circuits can be used to achieve the required performance. For production purposes electronic components with small tolerances can be used to ensure consistent performance or variable resistances may be used allowing fine-tuning of the electronic gains before permanent fixing. Waveforms of the form shown in Fig 5 (from a 5.5 MeV alpha particle creating an ion-track between two plates after amplification by amplifiers IC1 and IC2), are fed along electrical conductor 18 to a comparator IC4 (which may be a LP339 or similar) (Fig 6) and if they exceed the pre-set comparator threshold a logic signal is applied to the input of monostable IC5 (which may be a 74HCT423 or similar). If no signal from the vibration sensor exceeds the threshold on the comparator built around IC8 (which may be a LP339 or similar) the signal from monostable IC5 passes through IC6 (which may be a 74HCT423) to give a logic signal 20 to the digital logic circuit (not shown) that eventually drives the alarm and display unit (not shown). The digital logic circuits (not shown) may be implemented in many ways using a variety of electronic circuits and devices that are familiar to those skilled in the art. The alarm and display unit may take many forms and may have optical, audio or a combination of indication and alarm

features. However, if there is a simultaneous or shortly thereafter signal from the vibration sensor that is amplified by IC3 to give an output along electrical conductor 19 that does exceed the threshold of the comparator built around IC8 no signal is produced at 20. Instead a signal 21, indicating that the device was not available to count (a 'dead' time), is fed to the digital logic circuit (not shown) such that subsequent measurements of the rate of radioactive decays can be corrected to ensure that dead times are not included in the rate calculation. Additionally such dead times may be indicated by optical or audio signal or combination of to the user. Other electronic circuits can be used to achieve the desired performance.

In another embodiment of the invention (not shown) a plurality of vibration sensors with electronics to amplify signals and logic circuits to process these signals are provided within the electrically screened case 1 containing the electrodes. Disturbances that exceed a pre-set threshold or thresholds produce a signal that stops data acquisition (a 'dead time') until such disturbance cease. Such an arrangement would be useful in applications were the invention is subject to disturbances that may not be registered by one vibration sensor.

In another embodiment of the invention (Fig 7) the electrodes are two concentric electrically conducting cylinders 22 that are placed inside electrically screened enclosure 1 and isolated from the enclosure and spaced by insulators 23. Other electrically insulating supports that may contain vibration reducing materials (not shown) may be used to additionally secure the two electrodes and maintain their spacing to the inner surfaces of 1. Otherwise the mode of operation and associated components (not shown) are similar to those previously described in Fig 1 to Fig 6. One practical difference is that higher voltages are generally required between concentric cylinders than between parallel plates to collect air ions (not shown) created by alpha particle radiation.

In another embodiment of the invention (Fig 8) four parallel plate electrodes 24, 25, 26 and 27 are contained within enclosure 1. Additional electrically insulating supports (not shown) that may contain vibration reducing materials may be used to uniformly space the electrodes and to secure them to the inside of enclosure 1. Larger numbers of electrodes (not shown) could also be incorporated within the enclosure. Such an

embodiment is suited to measurement of high levels of airborne alpha particle radiation were the decays are so numerous that there is an appreciable probability for two decays to take place within the time resolution of the electronics. By using a plurality of electrodes the sensitive volume may be chosen so that at the highest level of radioactivity sampled the probability of more than one detectable decay occurring within the electronic time resolution is small. Accurate measurements can then be made. In this embodiment each adjacent electrode pair is equipped with amplifiers (not shown) and counting electronics (not shown). A plurality of pairs of concentric cylinders (not shown) may also be used.

In another embodiment of the invention (Fig 9) the electrodes consist of three parallel plates. The centre plate 12A is connected to a source of high voltage so that an electric field, sufficient to collect air ions (not shown), exists in regions 13A and 13B, between the centre plate and the other two plates 11A and 11B. Electronic amplifiers (not shown) connected by conductors 16A and 16B are provided to amplify air ion signals (not shown) detected on the two plates. A plurality of three electrode arrangements may be provided within enclosure 1.

Another embodiment of the invention is shown in Fig 10. In this embodiment there is provided a movable cover 30 in enclosure 1 that is placed over an aperture that contains an electrically conducting grid 29 of sufficient size to permit the ingress of radioactive dust, while maintaining electrical screening, into the sensitive region 13 between the electrodes. In normal operation the detector would be orientated so that dust would preferentially fall on this aperture. The cover 30 may be held in place covering grid 29 by pushing fitting 31 through holes 32 and 33. It may be moved by integral moving device 34 while being maintained in contact with the surface of enclosure 1 by guides 35 to a position such that grid 29 is not covered (as shown). It may then be secured by placing fitting 36 into hole 37. Subsequently if desired cover 30 may be moved so that grid 29 is covered. Many movements of the cover are possible. The cover may also be moved by a remotely controlled mechanism (not shown). Such an embodiment would be useful for detecting radioactive airborne alpha particle emitting materials in a form, such as dust when the diffusion of such material into enclosure 1 is unlikely.

In another embodiment (not shown) the apparatus of Figure 10 is provided without a diffusion aperture so that filter 9 and grid 8 and plate 7 are not required. All other ingress routes are sealed so radioactive nuclei that decay by emission of alpha particles may only enter the interior if cover 30 is moved to uncover grid 29. The cover may also be moved by a remotely controlled mechanism (not shown). Such a detector may have several applications including sampling radioactive dust by moving cover 30 clear of grid 29 and then resealing by moving cover 30 over grid 29. The count rate then measured, after allowing a period for the decay of any radon acquired during the sample period, will be free of radon decays.

In another embodiment a communication device (not shown) is attached to the detector so that the levels of airborne alpha particle radiation measured can be communicated to a plurality of similar detectors placed around a dwelling, office, factory, restaurant, shop or other buildings or in many different buildings. To validate operation and to assist with fault identification, diagnostic information may also be provided by appropriate electronics (not shown) and communicated to responsible persons. This embodiment may also have the ability to detect radioactive dust by moving a cover (not shown) of the form shown in Fig 10. The method of communication may be along electrical wire or wires, optical cable or cables, mains electric cables, by radio or similar means. In some embodiment the alarm and display module on each detector may have the capability (not shown) to indicate if the levels of alpha particle radiation on one or a plurality of other detectors has exceeded official guidelines and indicate which one or ones. For example (Fig 11) detector 38 placed in an underground room may register high levels of airborne alpha particle radiation while detectors 39 placed in rooms above may not, or vice versa. Additionally the detectors may be linked by suitable connection medium 40 to a computer 41 that with appropriate software can provide more information on the levels of airborne alpha particle radiation within the dwelling, office, factory, restaurant, shop or other buildings. It may also, if the connection to each detector supports duplex communication and each detector contains appropriate electronics (not shown) be used to reset the detectors, to change the detection thresholds and other such tasks as desired by the operator of the system or as may be mandated by future safety legislation.

In another embodiment (not shown) the detector is provided with a mechanism whereby it may transmit the measured levels of airborne alpha particle radiation, over the Internet, land-line telephone, fibre-optic network, satellite link, cellular phone or similar communications medium, to a distant office or several such offices. To validate operation and to assist with fault identification, diagnostic information may also be provided by appropriate electronics (not shown) and communicated to responsible persons. This embodiment may also have the ability to detect radioactive dust by moving a cover (not shown) of the form shown in Fig 10. The invention may be powered (not shown) by batteries, or from the mains grid or from solar cells with backups for periods of darkness or from combinations of, or from other similar supplies. The communication method may be of a duplex nature and electronics within the invention (not shown) may be such that a remote operator can re-set the detector and/or change the threshold levels, the duration over which data are acquired before being reported and similar operations that may be desirable. Such devices may be deployed (Fig 12) along known geographic fault lines 42 such as in California 43. Only a small number of detectors 44 are shown for illustrative purposes, in practice many more may be deployed, possibly some in subterranean locations, and they may report data along network 45 or various networks (not shown) to one centre 46 (as shown) or several centres (not shown) such as government offices and/or universities.

Although the sensitivity of the detectors to changes in atmospheric pressure, temperature and relative humidity are small, sensors that measure some or all of these quantities or other parameters that may be of interest such as wind speed and/or wind direction, may be incorporated into the alpha particle detectors with appropriate electronics so that corrections to the measured signals may be made and/or in cases were the detector is equipped with a communication device the value or values may be reported via a communication medium to users of the detector. Such sensor information may also be a useful diagnostic for malfunctioning detectors that are operated remotely.

In another embodiment of the invention (not shown) it may be combined with another sensor or a plurality of other sensors such as for smoke, carbon monoxide or optical or infra red cameras for security applications to create a multi-function device that may be convenient for some applications.

The foregoing description of the embodiments of the invention have been presented for purposes of illustration and description. They are not intended to be exhaustive or to limit the invention to the exact forms described. The embodiments were chosen to explain the principles of the invention and its practical applications. Changes may be made without departing from its spirit or affecting the principles upon which it is founded. It is intended that the scope of the invention be defined by the appended claims.

CLAIMS

1. A detector for airborne alpha particle emitting nuclei comprising an electrically screened container with an aperture covered by an electrically screened filter through which radon or other airborne alpha particle radioactive elements can ingress by diffusion into said container and/or with an aperture that may be closed off through which radioactive material such as dust may enter the container through an appropriately sized electrically screened filter, a plurality of electrodes mounted inside and electrically isolated from said container, adjacent electrodes being so separated that a fraction of the radioactive decays occurring within the space between adjacent electrodes may have short tracks striking the insensitive boundaries before producing sufficient numbers of ions to be detected so that the detection efficiency may be substantially less than 100%, a means for providing a substantially smooth high voltage so that an electric field of strength needed to collect air ions produced by alpha particle radioactive decay exists between adjacent electrodes, a means to provide electrical power to an electronic circuit board containing an electronic charge sensitive pre-amplifier and an amplifier with passive feedback components that provides large electronic gain only for the characteristic signals from radioactive decay and low gain for other signals, and an electronic amplifier to amplify signals from a vibration sensor or sensors mounted inside said container, and electronic digital logic circuits, said circuits being so arranged to convert analogue signals from the amplifiers to digital signals, to count the number of ion signals and record the live time when there is no vibration signal or signals and to convert measured decay rates into true decay rates, over a plurality of time periods, a display unit, optical or audio or both, to indicate measured airborne alpha particle rates, and alarms (optical, audio or both) for rates exceeding official safe levels and for dead time.

2. The alpha particle detector as described in claim 1 wherein the plurality of electrodes comprise a plurality of substantially equal sized parallel electrically conducting plates.

3. The alpha particle detector as described in claim 1 wherein the plurality of electrodes comprise two substantially concentric electrically conducting cylinders.

4. The alpha particle detector as described in claim 1 wherein the plurality of electrodes comprise a plurality of pairs of substantially concentric electrically conducting cylinders.

5. The alpha particle detector of claim 1 where a plurality of adjacent electrodes are arranged so that each one of a pair is provided with an electronic amplifier, the electrodes are sized so that at the highest levels of airborne alpha particle radiation to be measured the probability of more than one decay occurring within the electronic time resolution is small.

6. The alpha particle detector as described in claim 1 wherein the plurality of electrodes comprises three substantially parallel and substantially equal sized electrically conducting plates so arranged that one plate is placed between the other two and connected to a high voltage so as to create an electric field between it and each of the other plates such that signals from air ions created between the high voltage plate and either of the other plates can be detected on these plates which are each provided with electronic amplifiers, the electrodes maybe sized so that at the highest levels of airborne alpha particle radiation to be measured the probability of more than one decay occurring within the electronic time resolution is small, a plurality of groups of three plates may be provided.

7. The alpha particle detector of any one of claims 1 2 3 4 5 6 where the said electrically screened container is provided, at a suitable point with a movable, either by hand or remote controlled mechanism, cover over an aperture that contains an electrically conducting grid of sufficient size to permit the ingress of radioactive dust between internal electrodes while maintaining electrical screening, the cover

may be moved so as to include or exclude the possibility of the ingress of dust into the enclosure.

8. The alpha particle detector of claim 7 where no diffusion aperture is provided and the only method of ingress into the enclosure is by moving the cover, either by hand or remote controlled mechanism, the cover may at some later period be moved so that no additional alpha particle radioactive material may enter.

9. The alpha particle detector of any one of claims 1 2 3 4 5 6 7 8 which are provided with communication equipment and other electronics such that the apparatus may communicate with another or a plurality of similar devices in a building and/or several buildings and/or with a computer or a plurality of computers equipped with appropriate software, communication protocol may be duplex allowing devices to reset each other and allowing control of each device from another or from a computer or a plurality of computers.

10. The alpha particle detector of any one of claims 1 2 3 4 5 6 7 8 which are provided with communication equipment and other electronics that allows communication of measurements over a network, such as the Internet, satellite links or similar, to a central office or offices so that a large area may be monitored for airborne alpha particle radiation, the communication protocol may be duplex allowing a central computer or computers equipped with appropriate software to reset each detector and/or allowing changes in acquisition parameters.

11. The alpha particle detector of any one of claims 1 2 3 4 5 6 7 8 9 10 where a atmospheric pressure sensor and/or a wind sensor and/or a direction of wind sensor and appropriate electronics is provided so that measurements may be corrected for pressure and wind changes and so that the operator may be informed of said changes in atmospheric conditions.

12. The alpha particle detector of any one of claims 1 2 3 4 5 6 7 8 9 10 where a relative humidity sensor and appropriate electronics is provided so that measurements may be corrected for changes in relative humidity and so that the operator may be informed of said relative humidity.

13. The alpha particle detector of any one of claims 1 2 3 4 5 6 7 8 9 10 where a temperature sensor and appropriate electronics is provided so that measurements may be corrected for changes in temperature and so that the operator may be informed of said temperature.

14. The alpha particle detector of any one of claims 1 2 3 4 5 6 7 8 9 10 where they are combined with another sensor or a plurality of other sensors such as for smoke, carbon monoxide or optical or infra red cameras for security applications to create a multi-function device that may be convenient for some applications.

15. The alpha particle detector of any one of claims 1 2 3 4 5 6 7 8 9 10 where the means for providing the high voltage and power for the electronic modules are an internal battery or a plurality of internal batteries with a method of indicating to the user when the batteries need replacing or if rechargeable batteries are used when they need recharging.

16. The alpha particle detector of any one of claims 1 2 3 4 5 6 7 8 9 10 where the means for providing the high voltage and power for the electronic modules is mains electricity.

17. The alpha particle detector of any one of claims 1 2 3 4 5 6 7 8 9 10 where the means for providing the high voltage and power for the electronic modules is derived from a solar panel or panels or other solar powered source with appropriate backup for periods of darkness and low light.

18. The alpha particle detector of any one of claims 1 2 3 4 5 6 7 8 9 10 where the means for providing the high voltage is a Dry Pile sometimes known as a Dulac or Zamboni Pile.

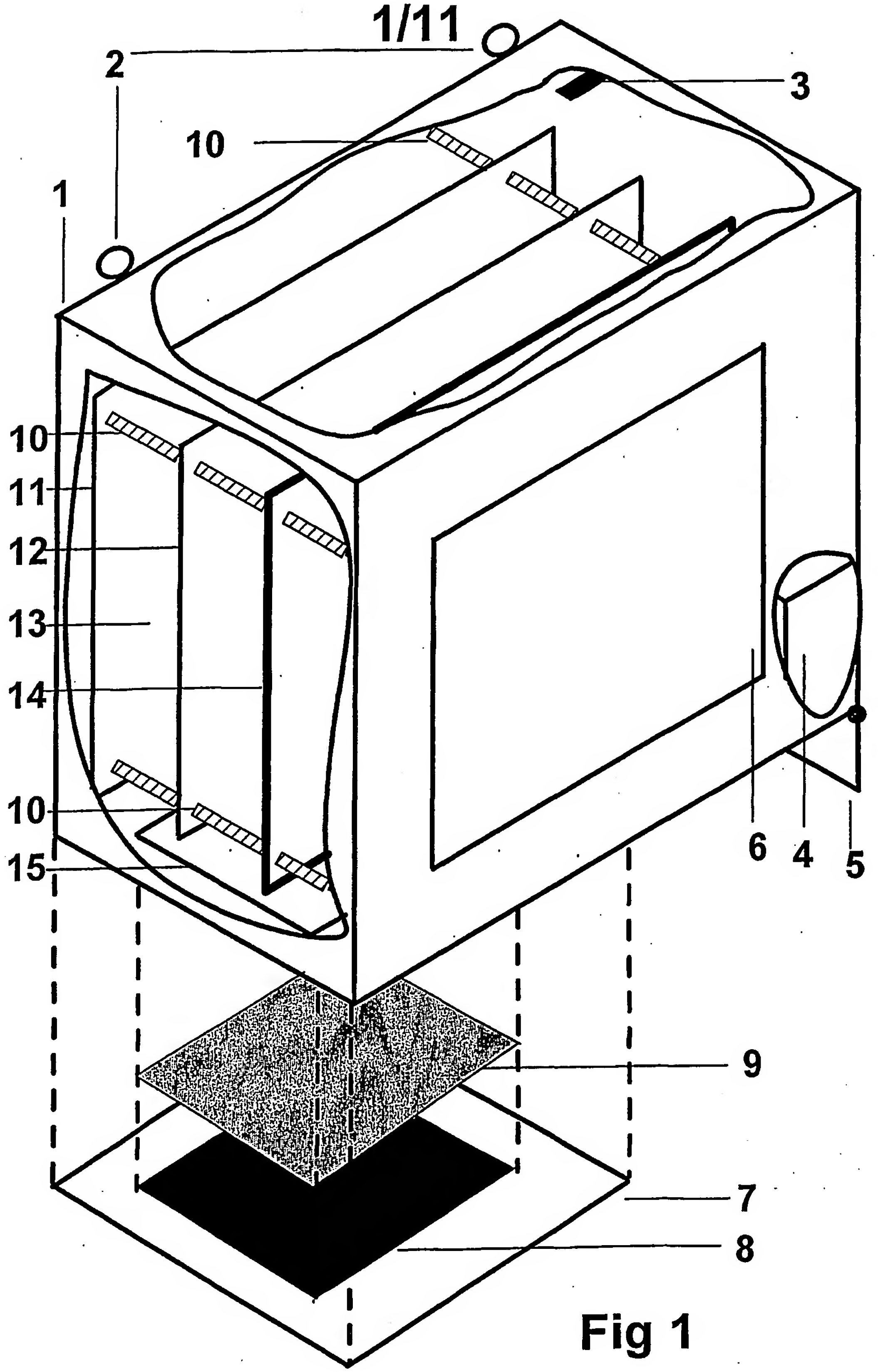


Fig 1

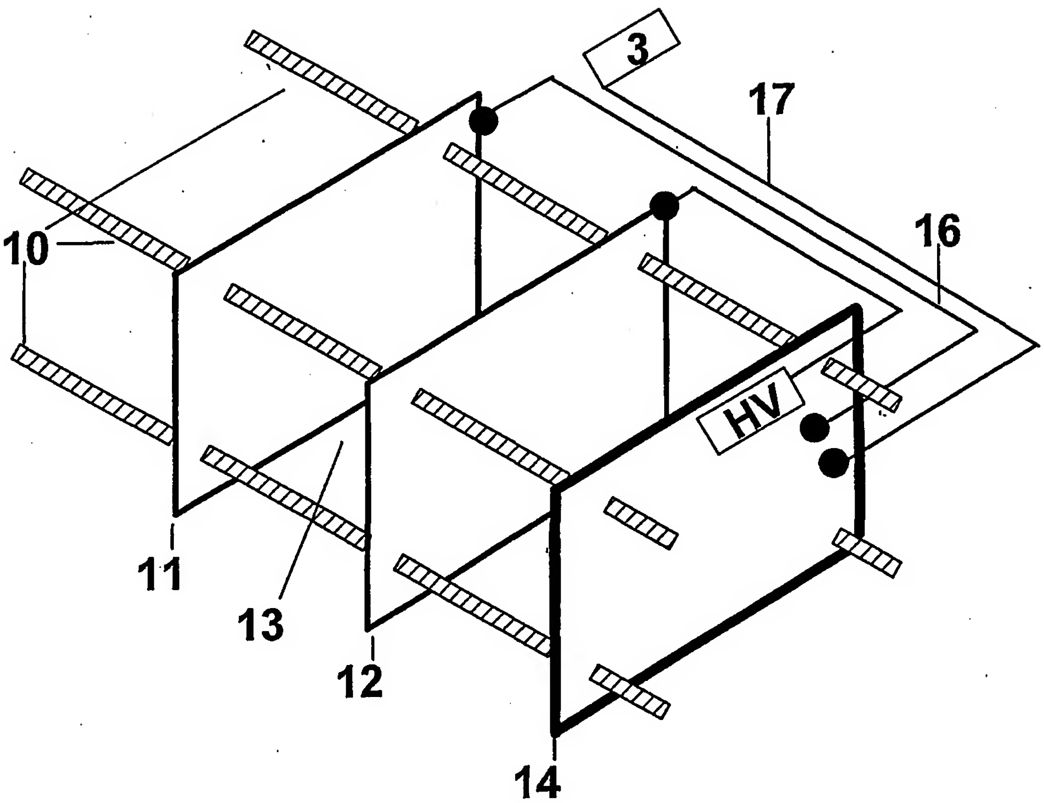


Fig 2

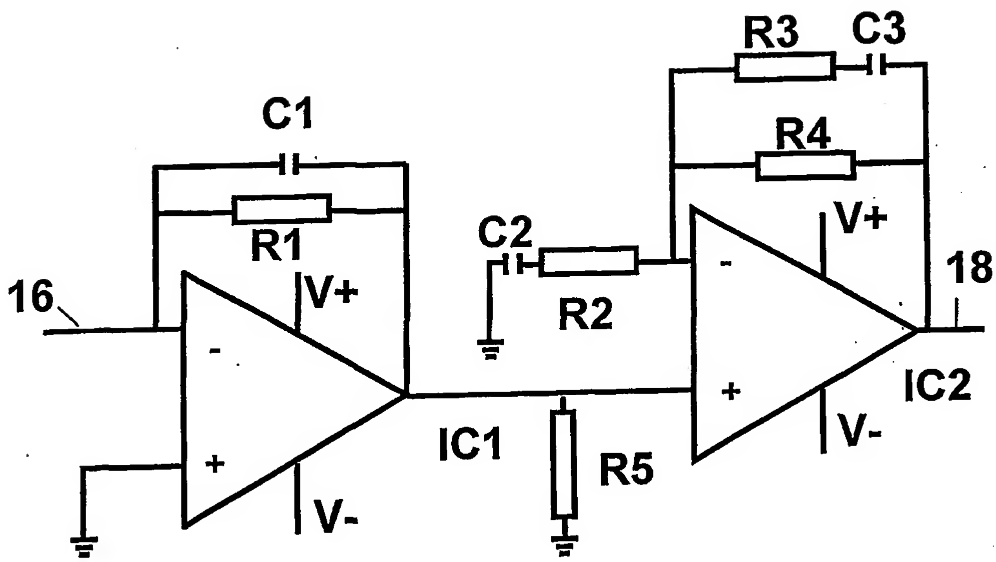


Fig 3

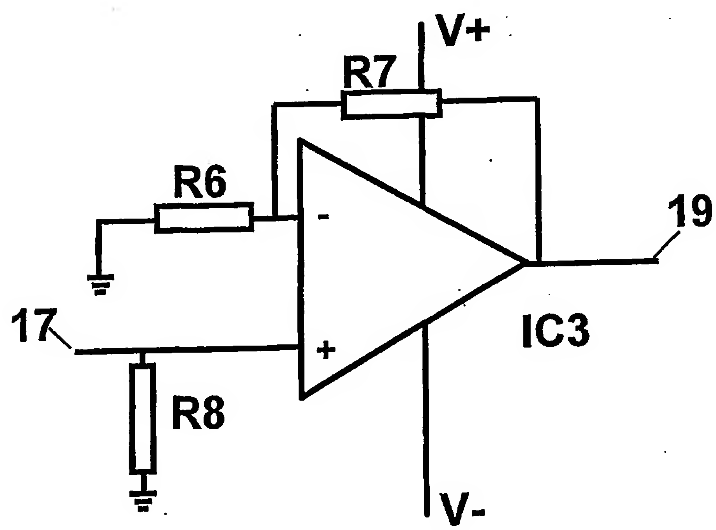


Fig 4

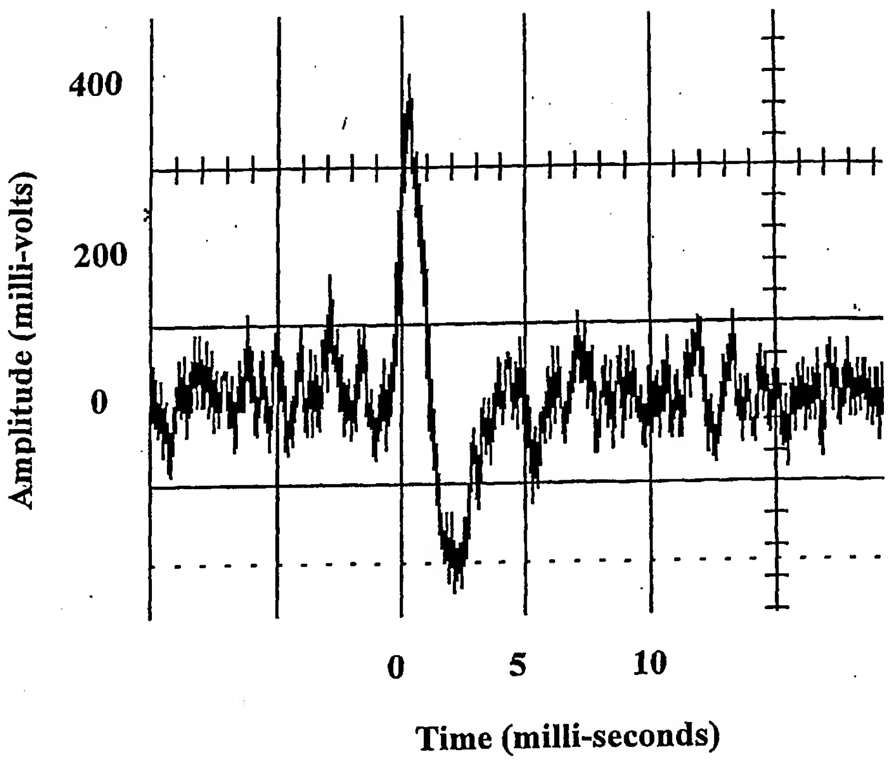


Fig 5

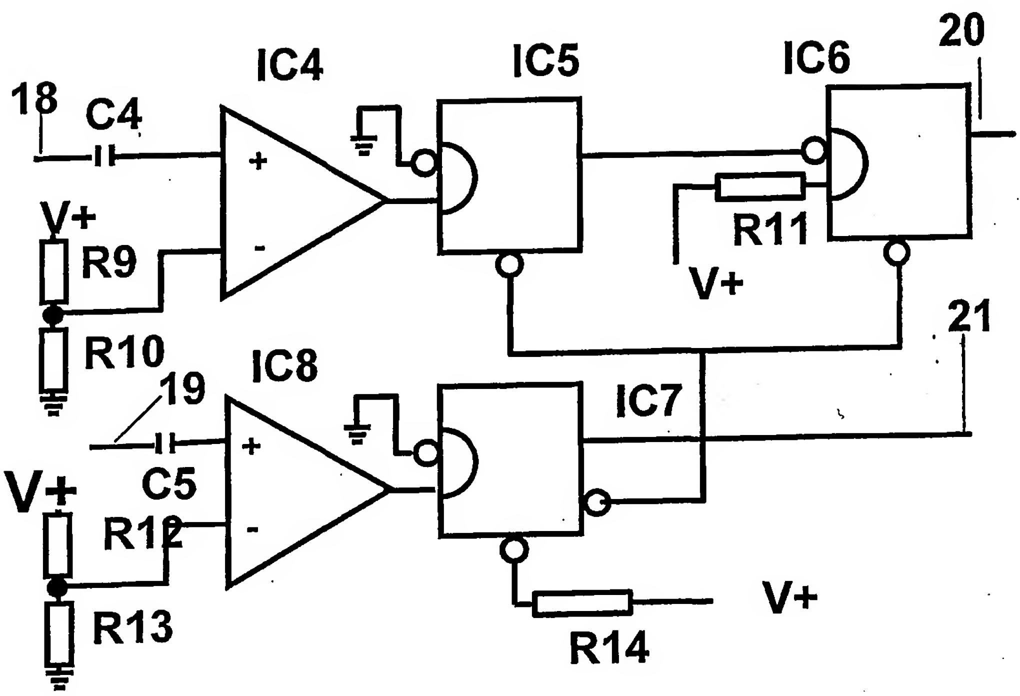


Fig 6

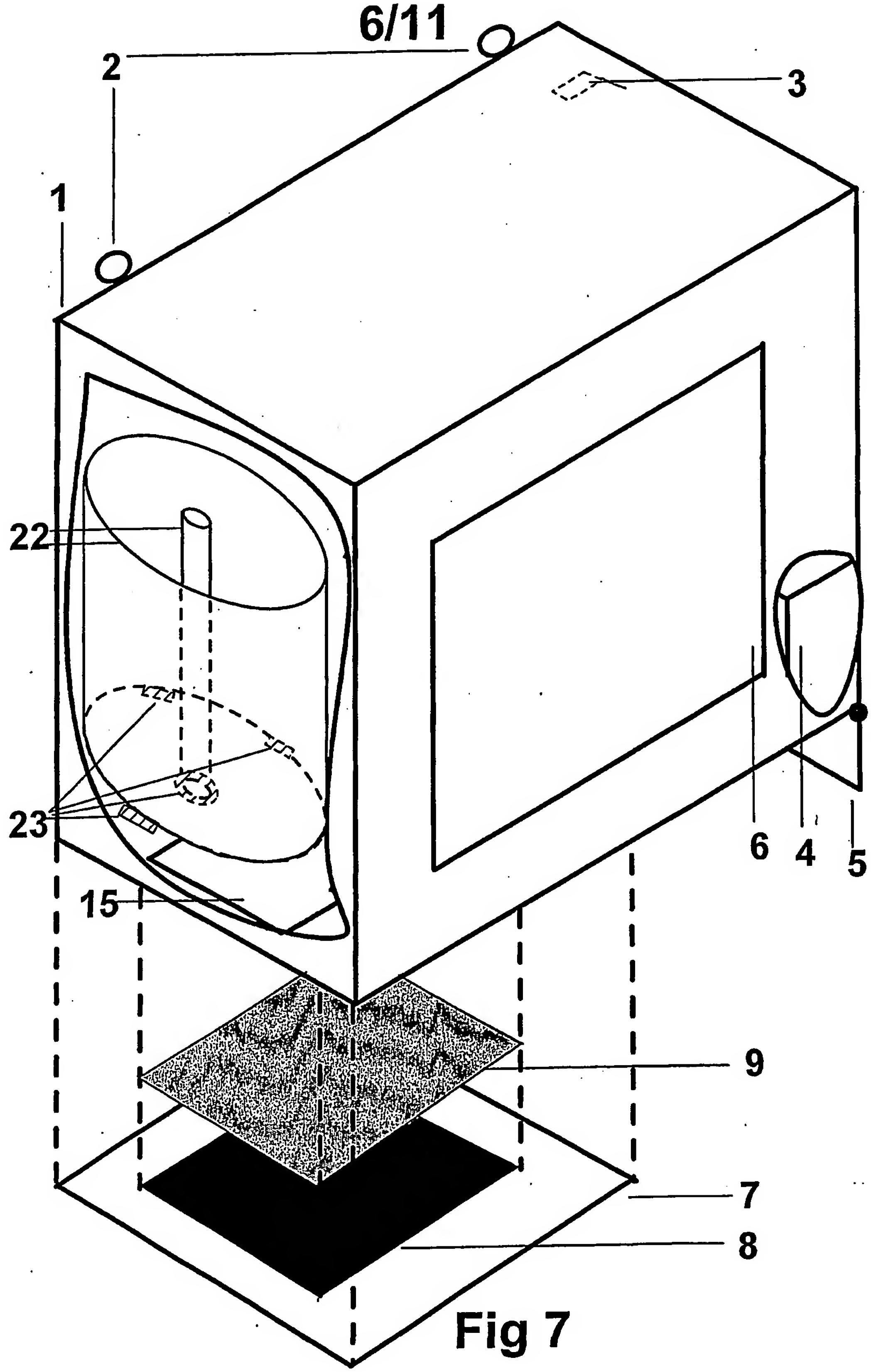


Fig 7

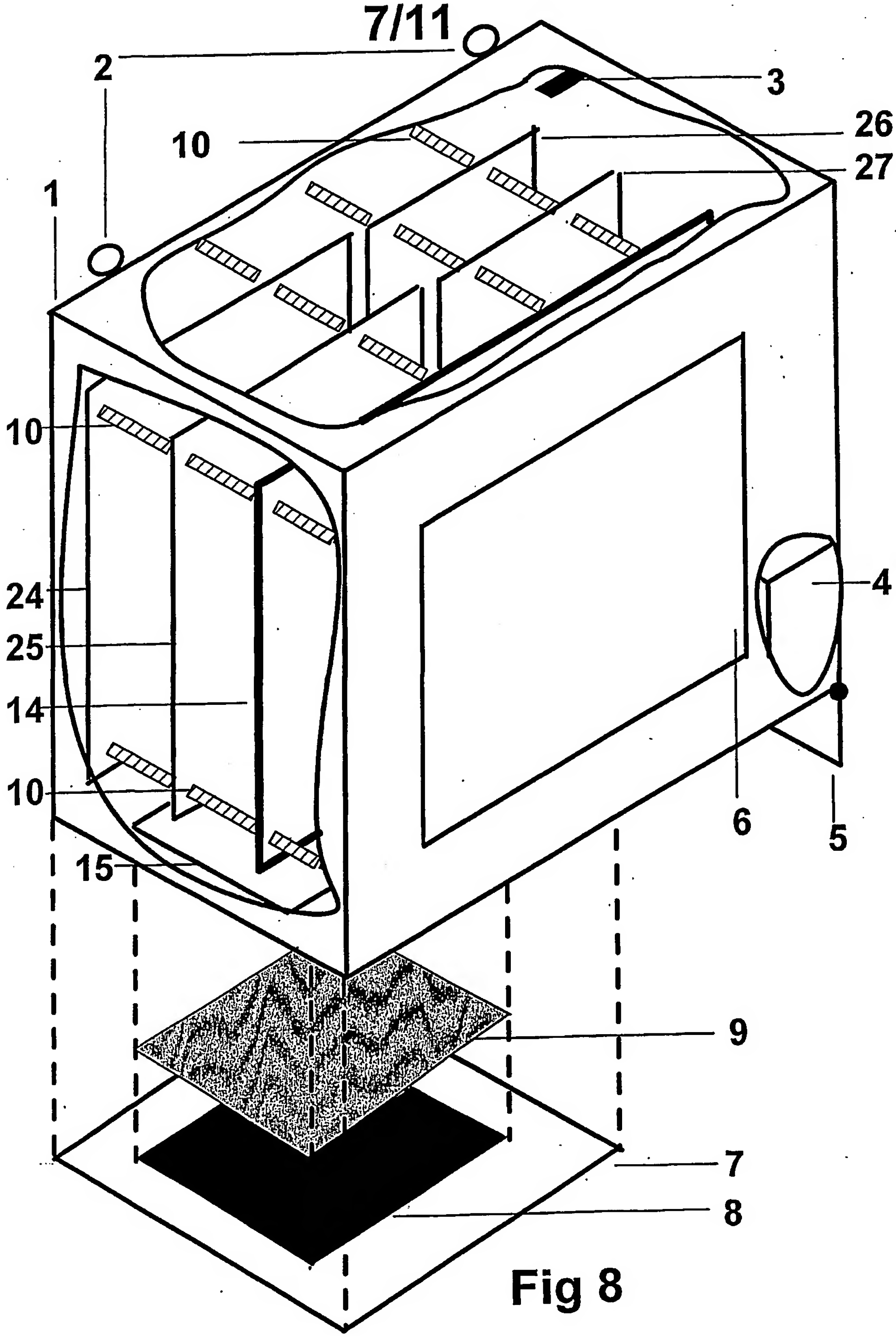


Fig 8

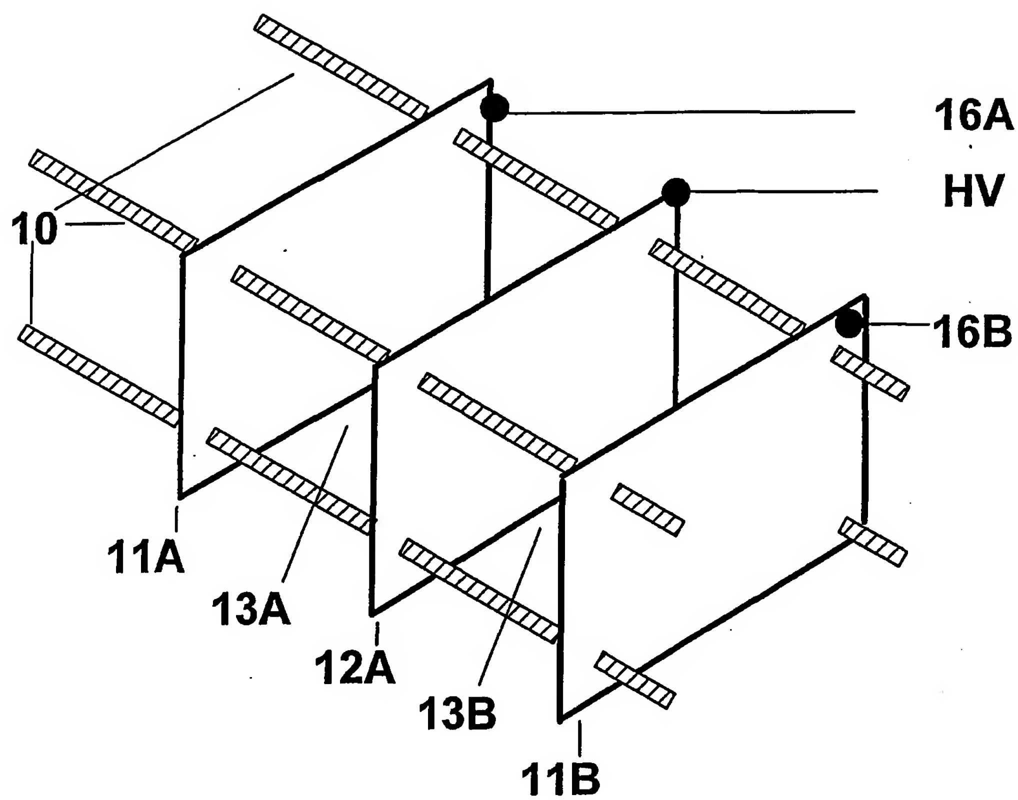


Fig 9

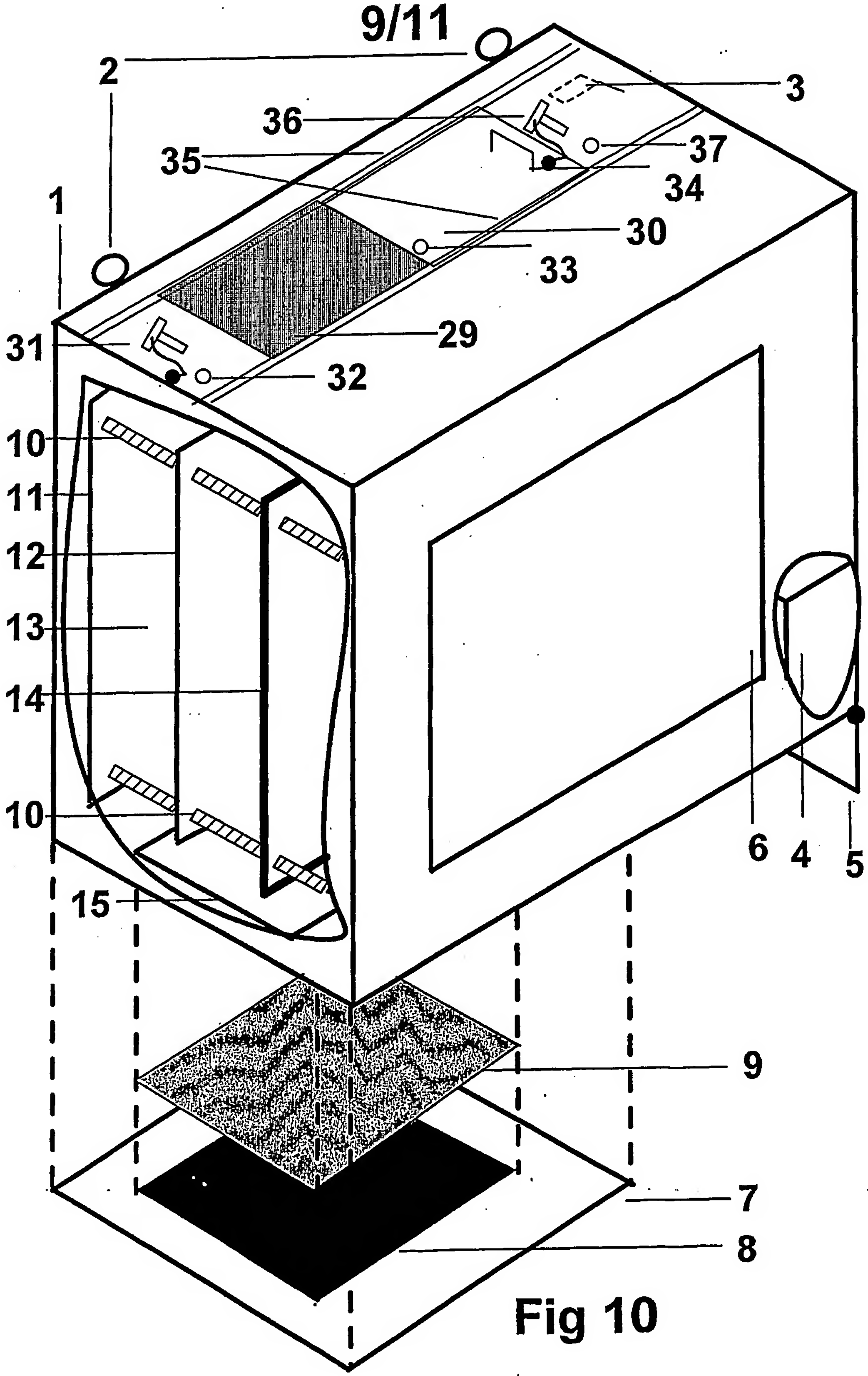


Fig 10

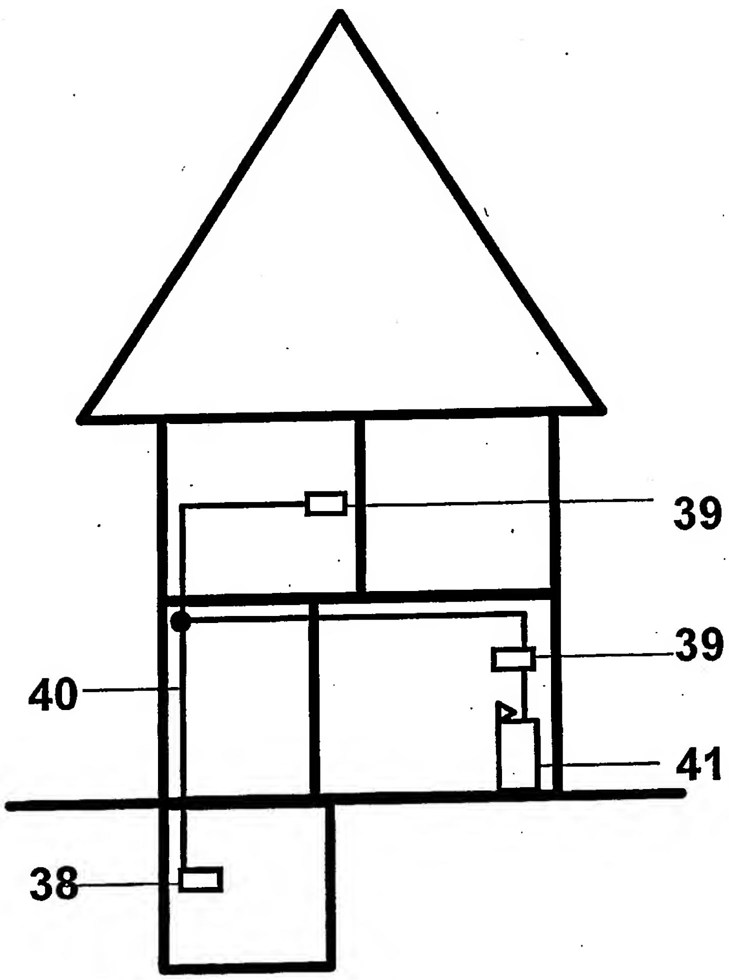


Fig 11

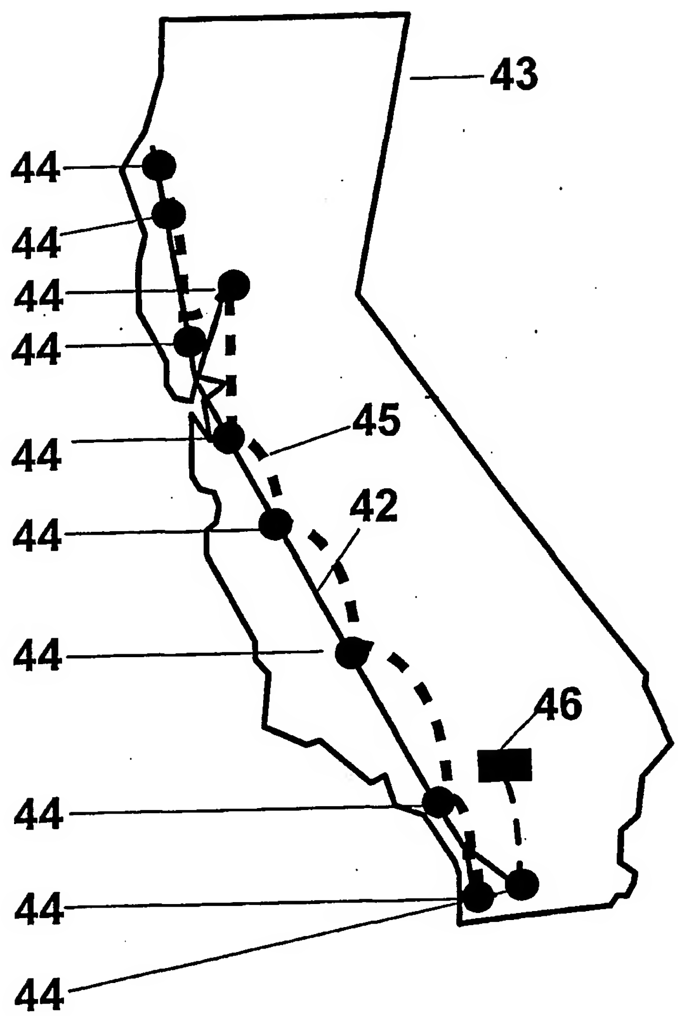


Fig 12

INTERNATIONAL SEARCH REPORT

Interr al Application No
PCT/GB 01/04266

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01T1/178

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01T

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, INSPEC, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 550 381 A (BOLTON RICHARD D ET AL) 27 August 1996 (1996-08-27) page - column 1, line 53 - line 61 column 2, line 54 -column 3, line 7 column 4, line 12 -column 5, line 36 column 6, line 15 - line 21 figures 2,3 ---	1,2,15
A	NEGRO V C: "RADOMETER - A PORTABLE FIELD INSTRUMENT FOR THE RAPID MEASUREMENT OF ENVIRONMENTAL RADON AND THORON" IEEE TRANSACTIONS ON NUCLEAR SCIENCE, IEEE INC. NEW YORK, US, vol. 37, no. 2, 1 April 1990 (1990-04-01), pages 854-858, XP000142938 ISSN: 0018-9499 p854 section II -p857 section III ---	1,3,7,8, 12,13,15

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 January 2002	28/01/2002

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Datta, S

Interr al Application No
PCT/GB 01/04266

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 859 865 A (VANDENBURGH HERMAN H) 22 August 1989 (1989-08-22) column 2, line 7 - line 30 column 3, line 29 - line 40 column 3, line 47 - line 68 column 4, line 17 - line 36	1,9, 11-13,16

Information on patent family members

Inter al Application No
PCT/GB 01/04266

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 5550381	A	27-08-1996	NONE	
US 4859865	A	22-08-1989	NONE	